The MICROLAS concept

Precise thrust generation in the µN range by laser ablation

Stefan Scharring, Raoul-Amadeus Lorbeer, Stephanie Karg, and Hans-Albert Eckel

Institute of Technical Physics, German Aerospace Center

Motivation

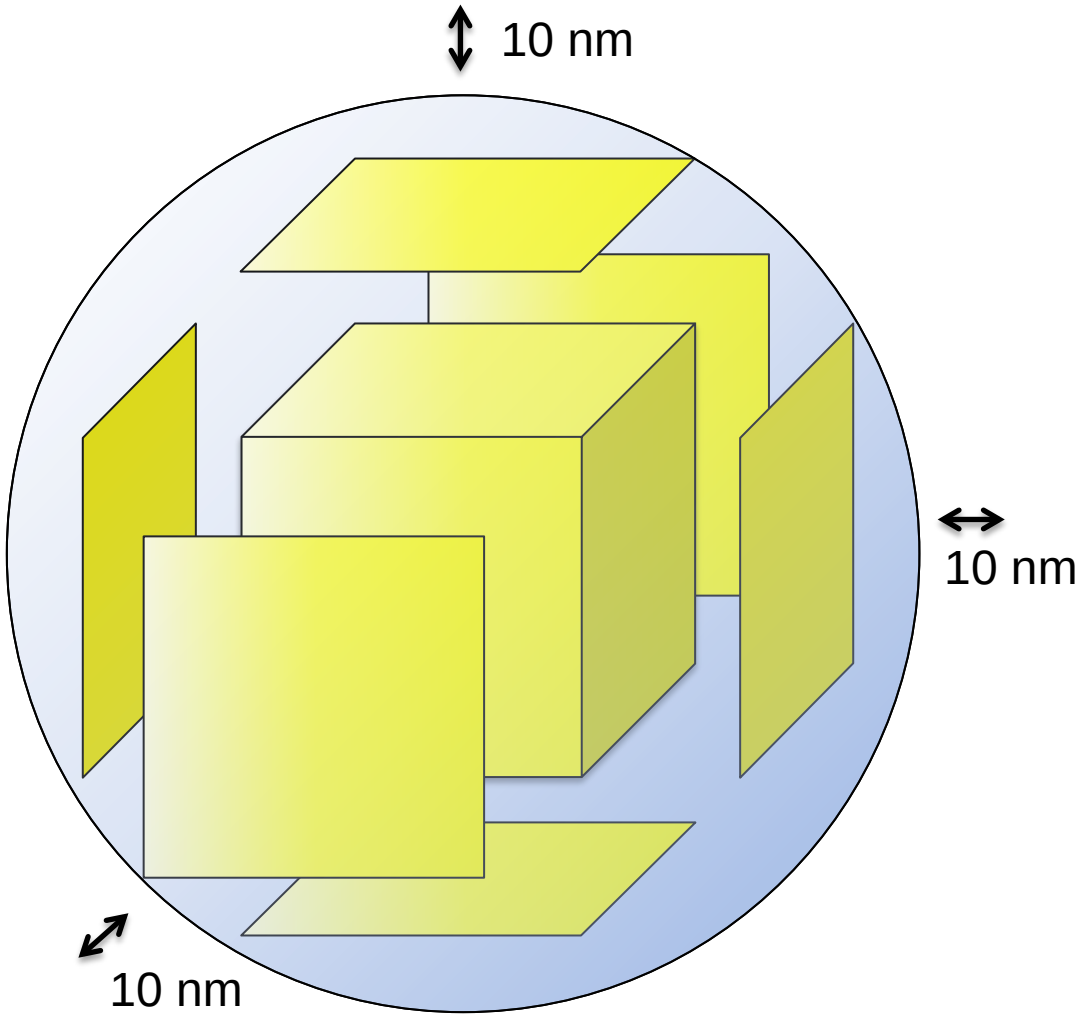
High precision
drag free / free fall
scientific missions:

eLISA / NGO,

MICROSCOPE,

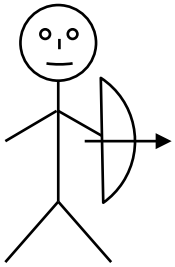
DECIGO,

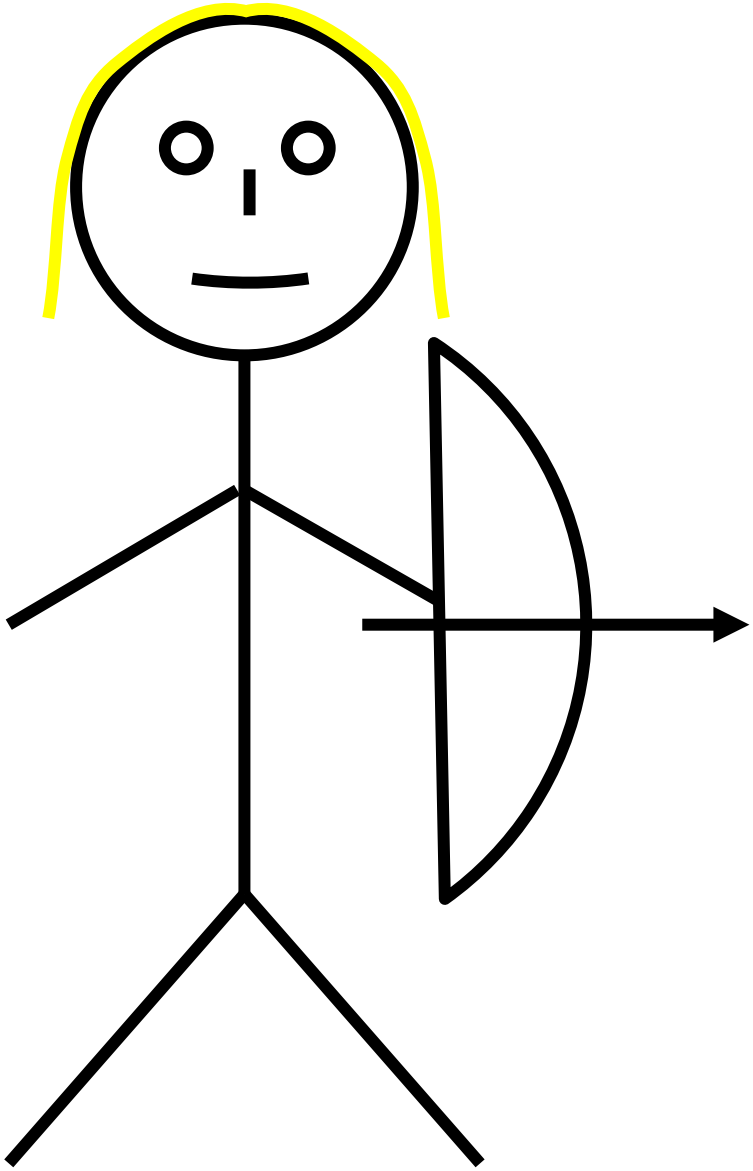
…



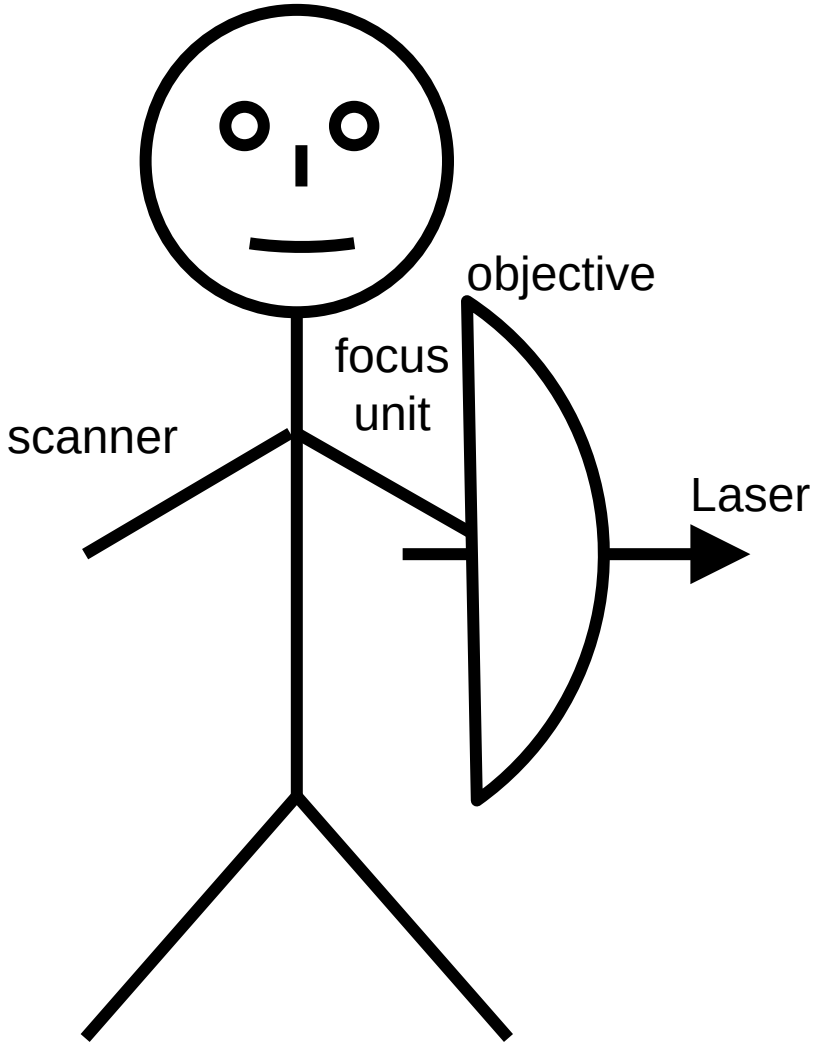
MICROLAS

- Tolkien's "The Lord of the Rings":
  "Legolas' very small brother."





MICROLAS



MICROLAS

Laser

EO scanner

EO focus unit

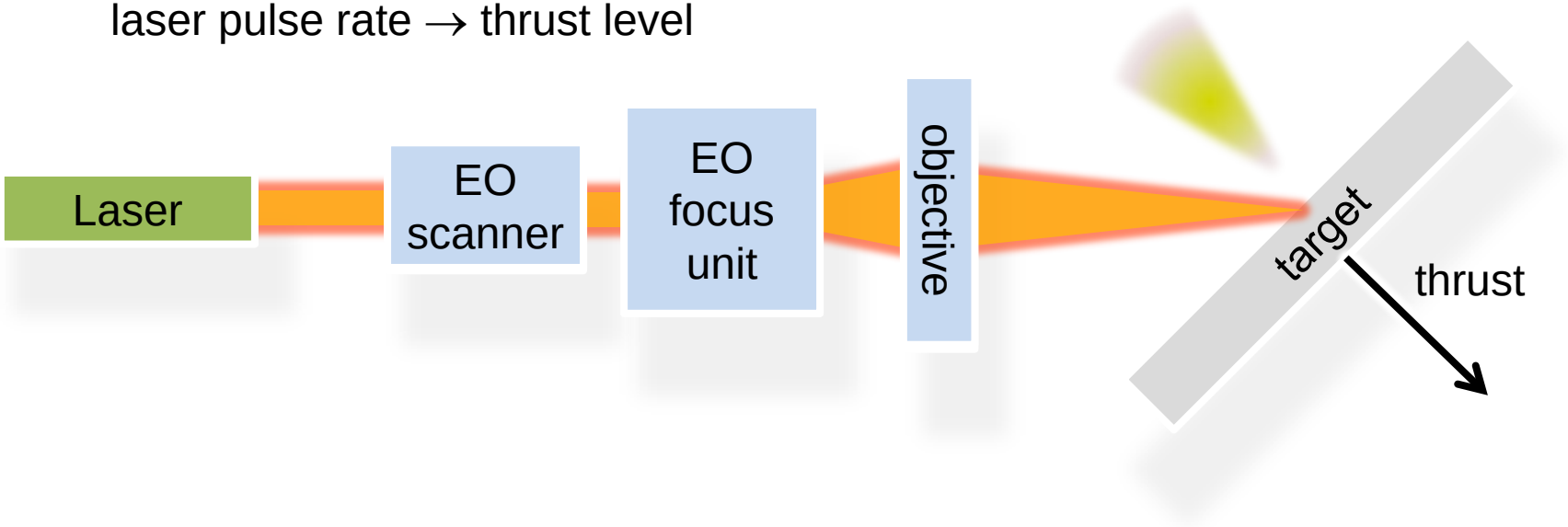
objective

target

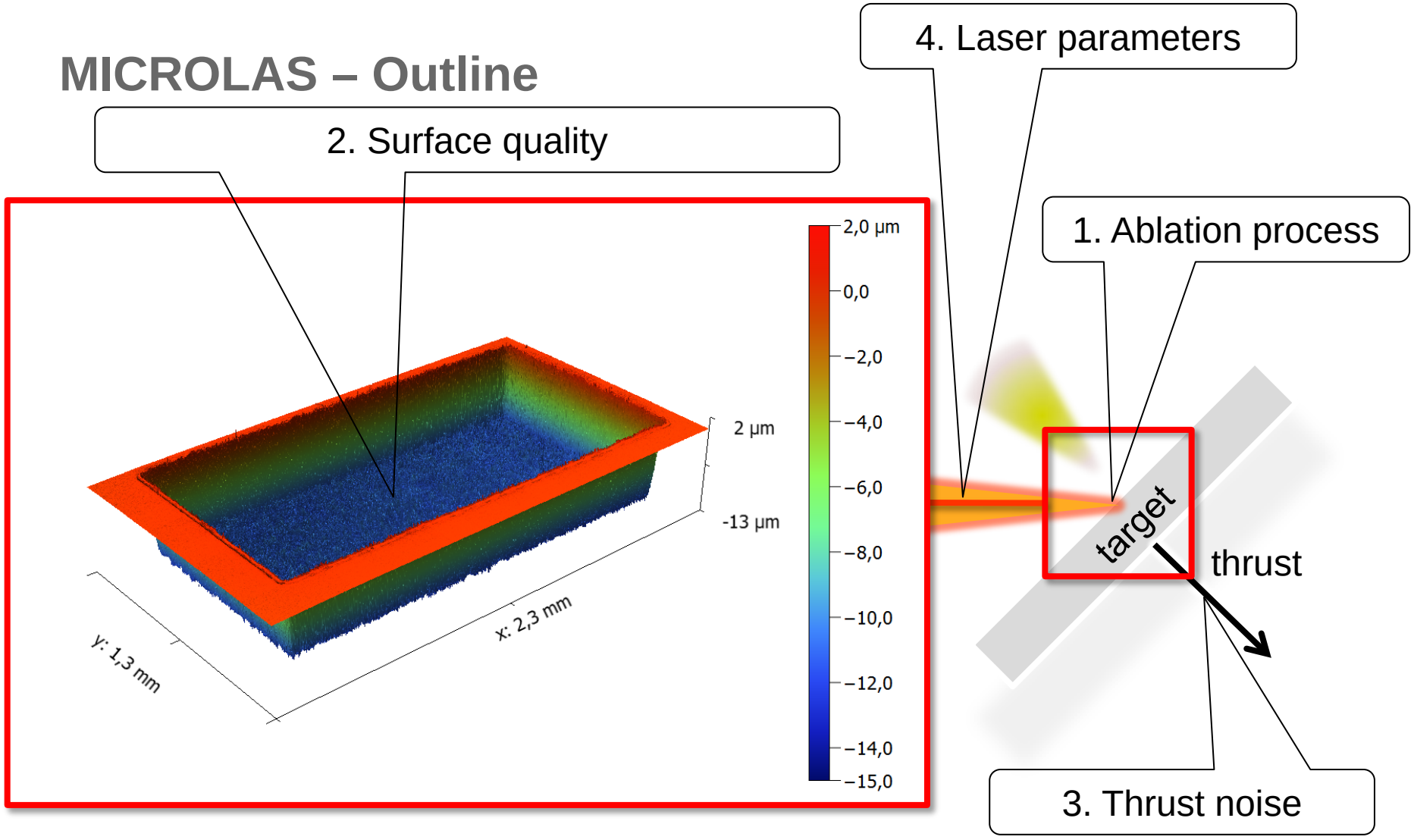
no moving parts
→ low thrust noise

MICROLAS

laser pulse rate → thrust level



MICROLAS – Outline

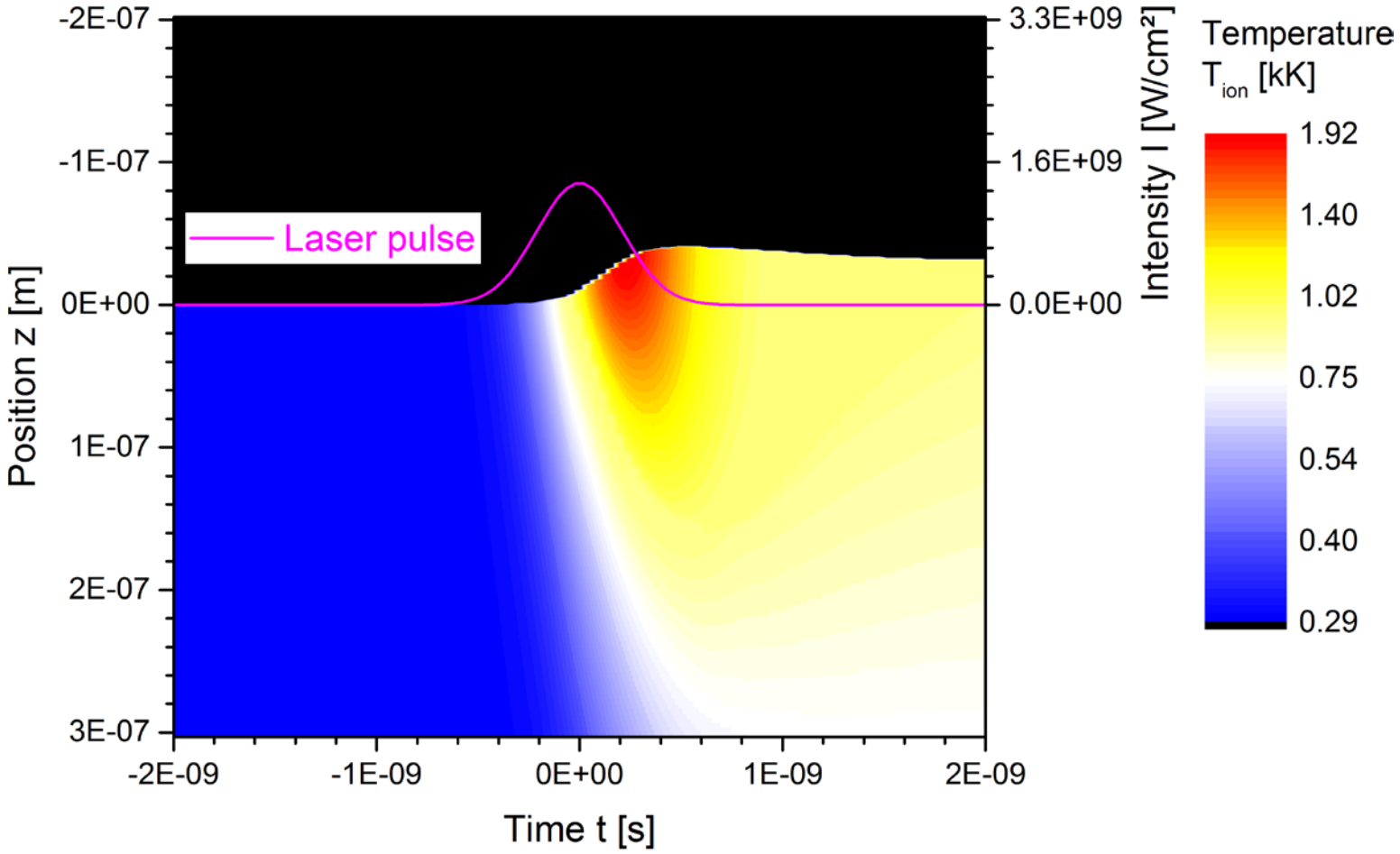


Laser ablation and propulsion

Shortpulse and ultra-short pulse ablation

Simulation of Laser-Matter Interaction

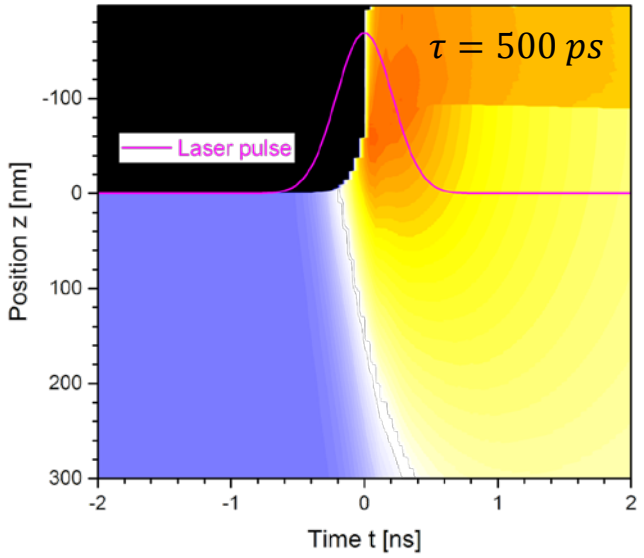
Hydrodynamic simulations with Polly-2T code (JIHT-RAS Moscow)
1D-Two-Temperature Model for Laser-Matter-Interaction with Metals

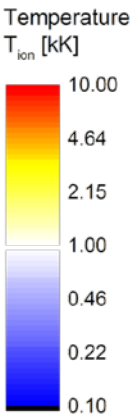


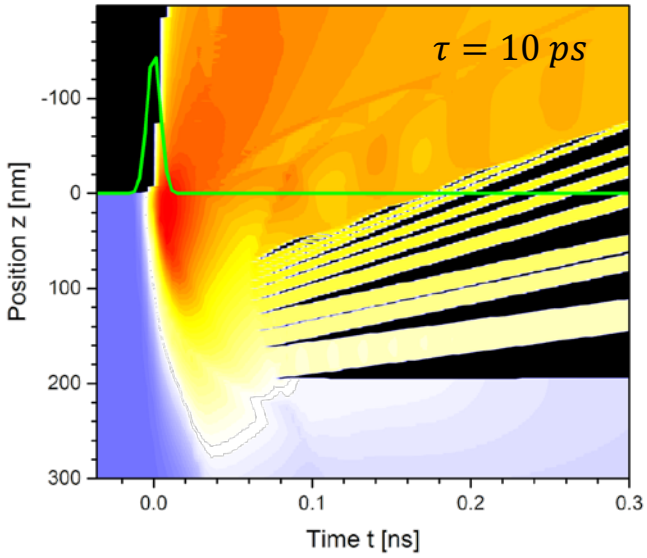
Laser: $\lambda = 1064\,nm, \tau = 500\,ps, \vartheta = 0°$, lin.pol., $\Phi = 0.74\,J/cm^2$, $I_{max} = 1.41\ GW/cm^2$, Target: Al

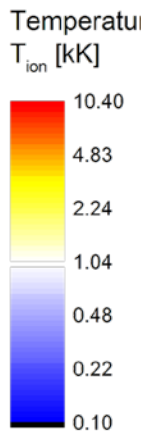
Polly-2T simulations
$\lambda = 1064\,nm, \vartheta = 0°$, circ.pol., $\Phi = 1.49\,J/cm^2$, Al

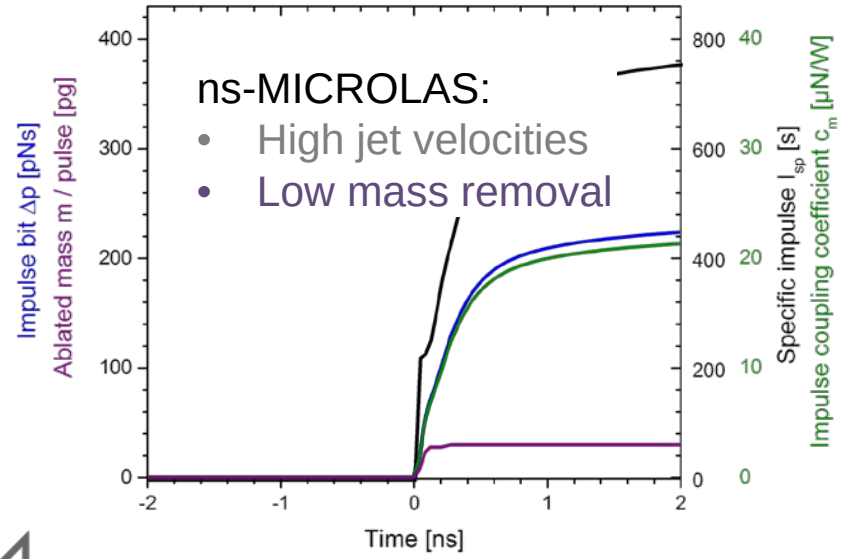
Propulsion: Short pulse vs. ultrashort pulse laser ablation

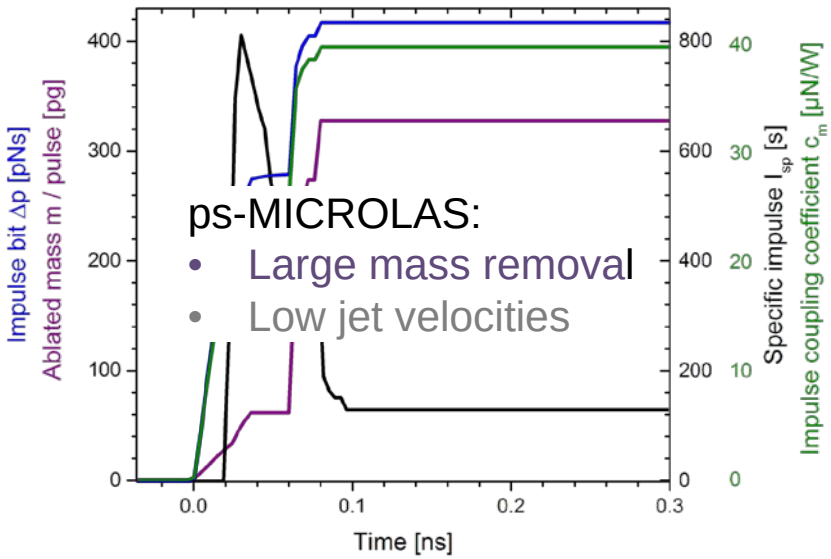








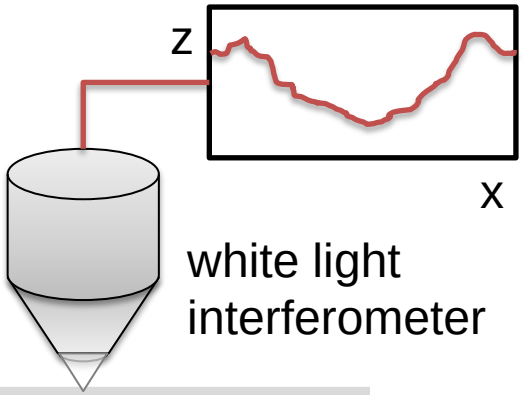




The challenge of surface quality

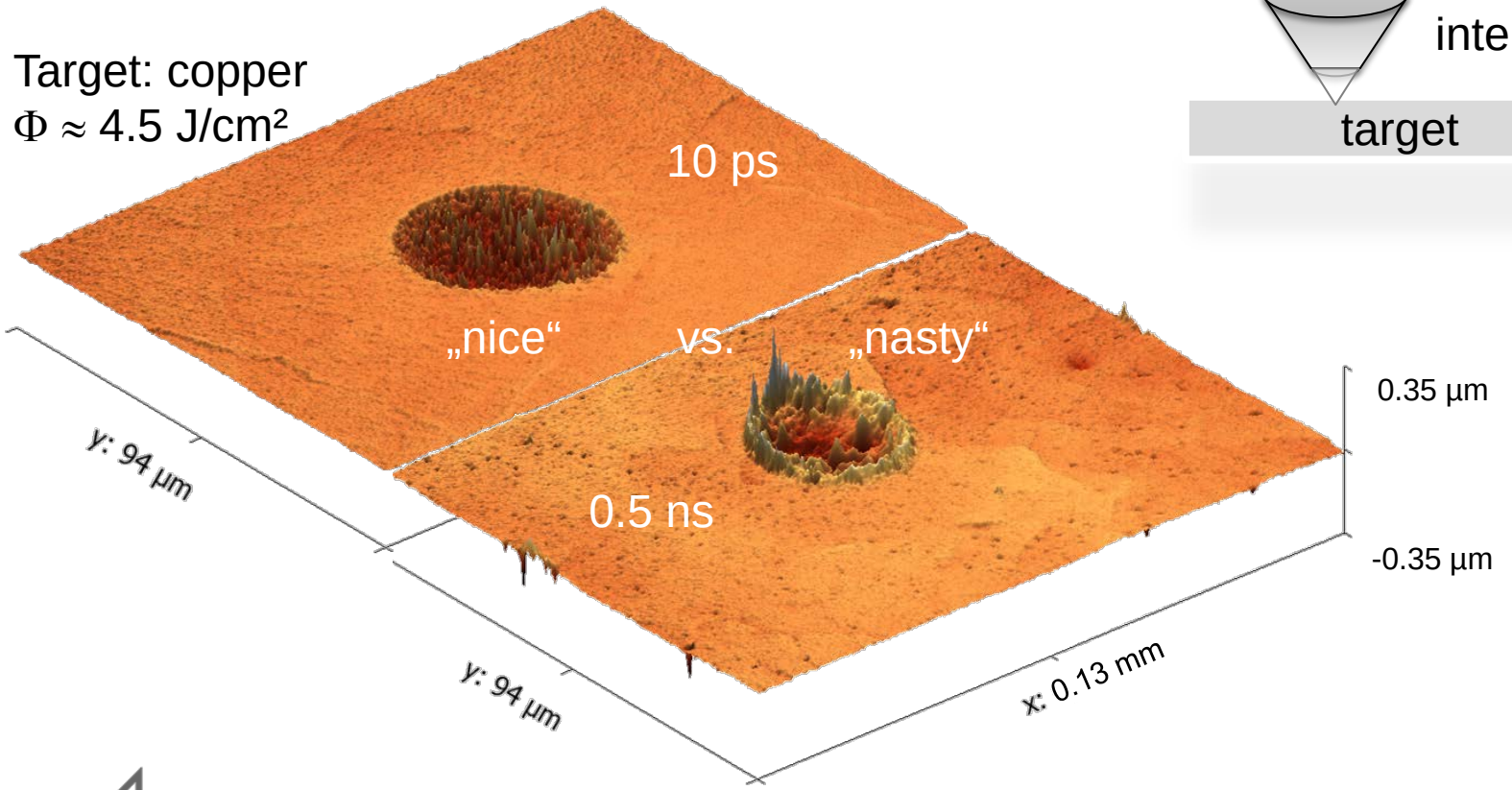
ps-MICROLAS vs. ns-MICROLAS

ps-laser material processing provides smooth holes



Surface roughness:

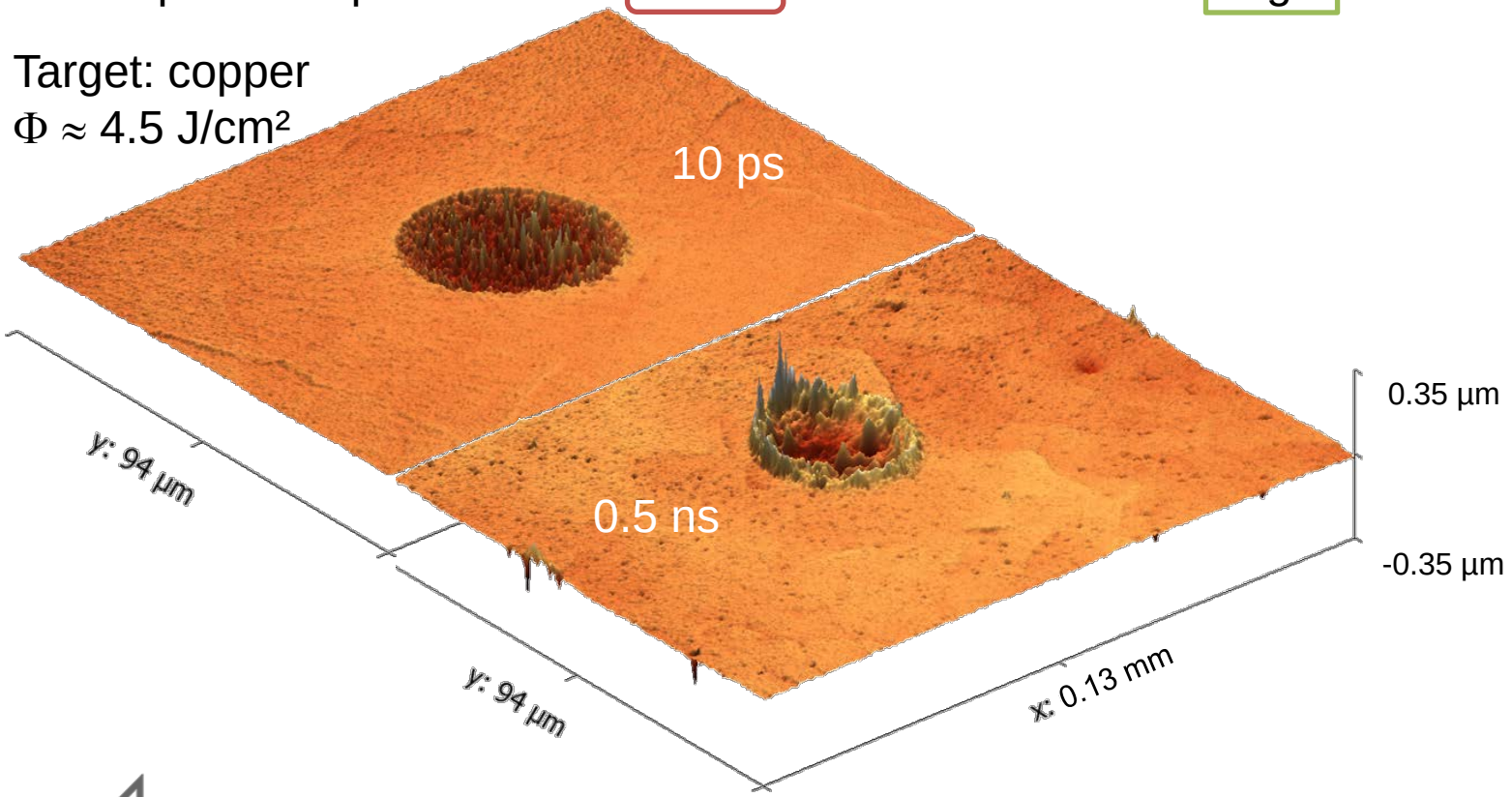
Target: copper
$\Phi \approx 4.5$ J/cm²



ps- and ns-MICROLAS tradeoff has to be found

- Process: spallation vs. vaporization
- Surface roughness: „nice“ vs. „nasty“
- Specific impulse: low vs. high

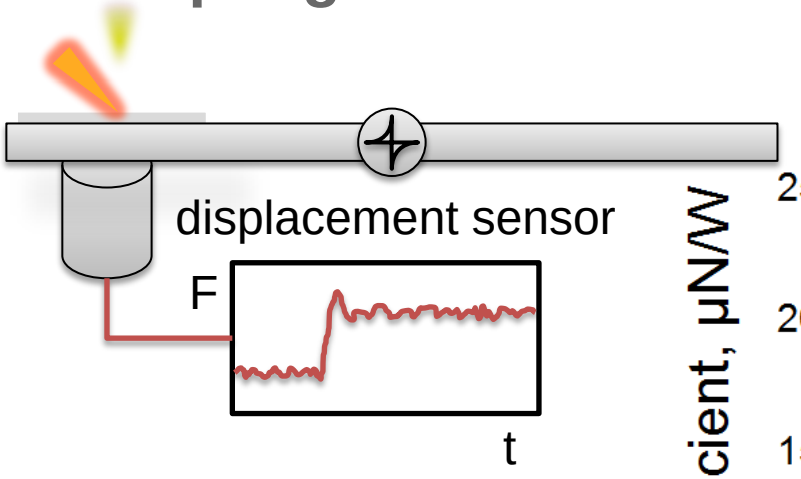
Target: copper
$\Phi \approx 4.5$ J/cm²



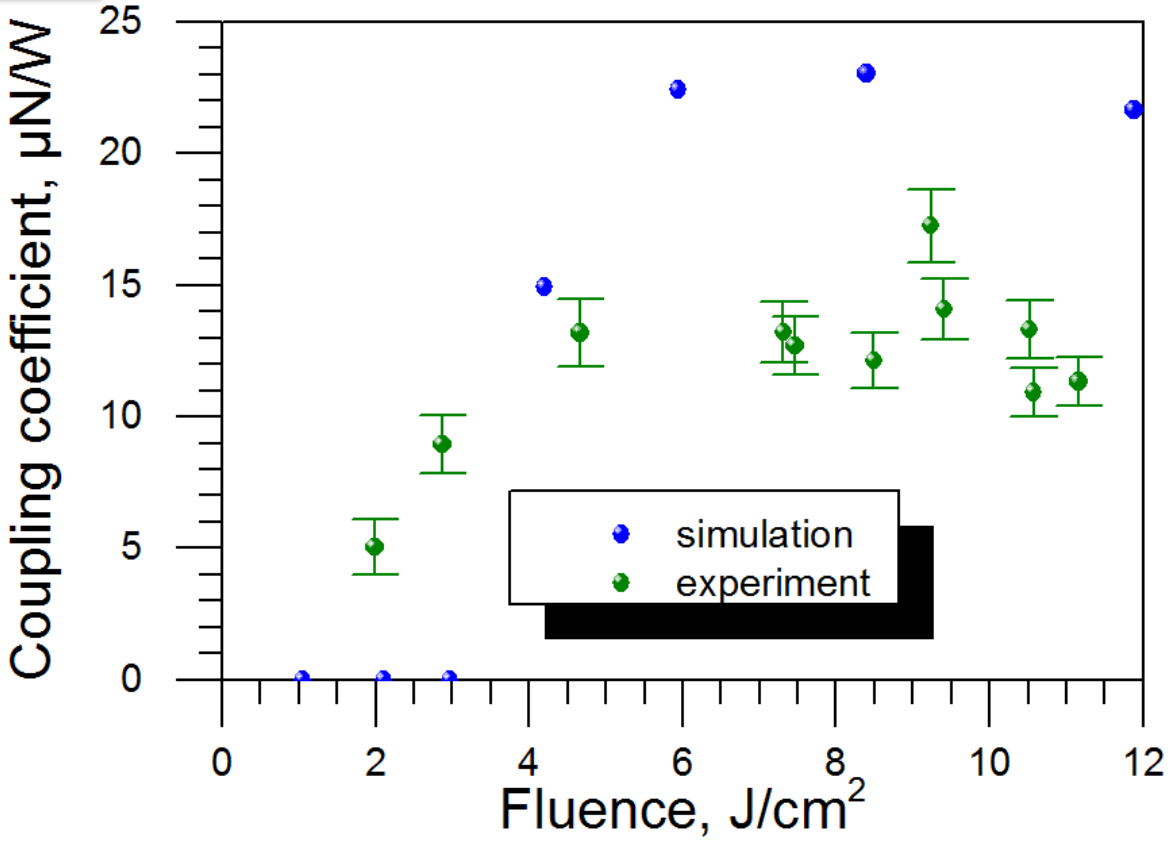
The challenge of thrust noise

Thrust characteristics of ns-MICROLAS

Coupling coefficients of sim. and exp. are comparable



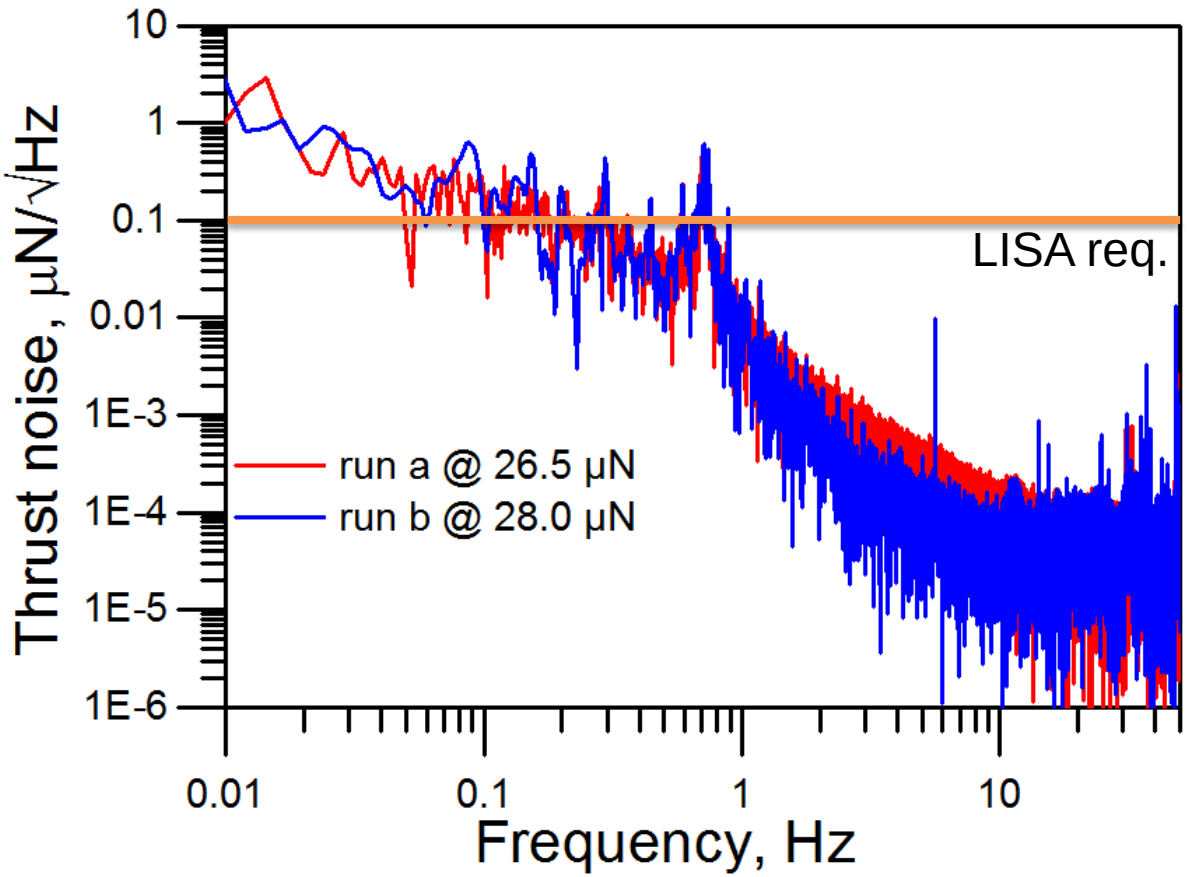
- Pulse duration
  τ = 8 ns
- Laser-wavelength
  λ = 1064 nm
- Aluminum



* Results from HD simulations with Polly-2T, code provided from M. Povarnitsyn, JIHT-RAS. Online version (VLL) accessible at http://vll.ihed.ras.ru/

Thrust-noise of ns-MICROLAS vs. LISA requirements

- Pulse duration
  τ = 8 ns
- Laser-wavelength
  λ = 1064 nm
- Aluminum
- Pulse rate
  f = 1 kHz

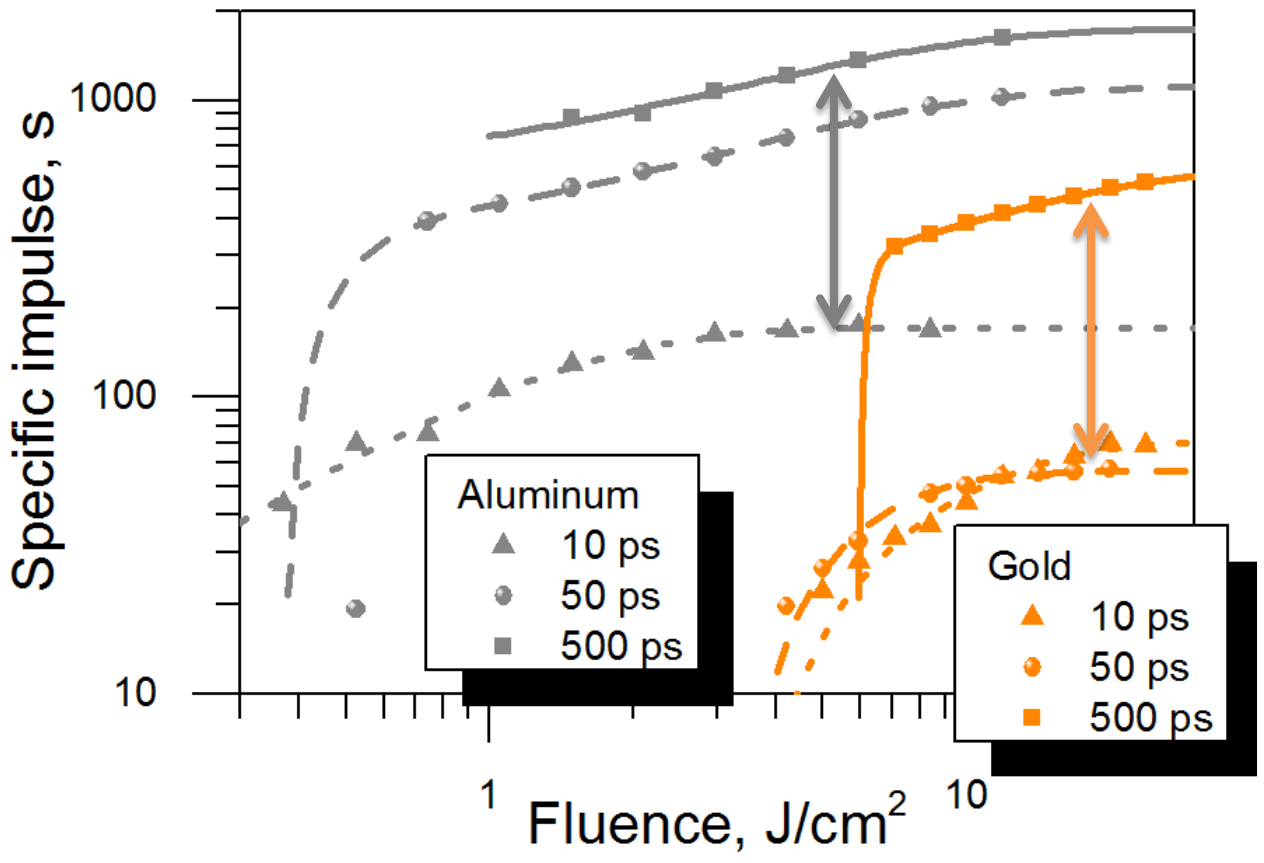


The optimum working point

Process parameter optimization

Specific impulse depends on material and pulse duration

- Laser-wavelength
  λ = 1064 nm
- Angle of incidence
  ϑ = 0°
- Circular
  polarization



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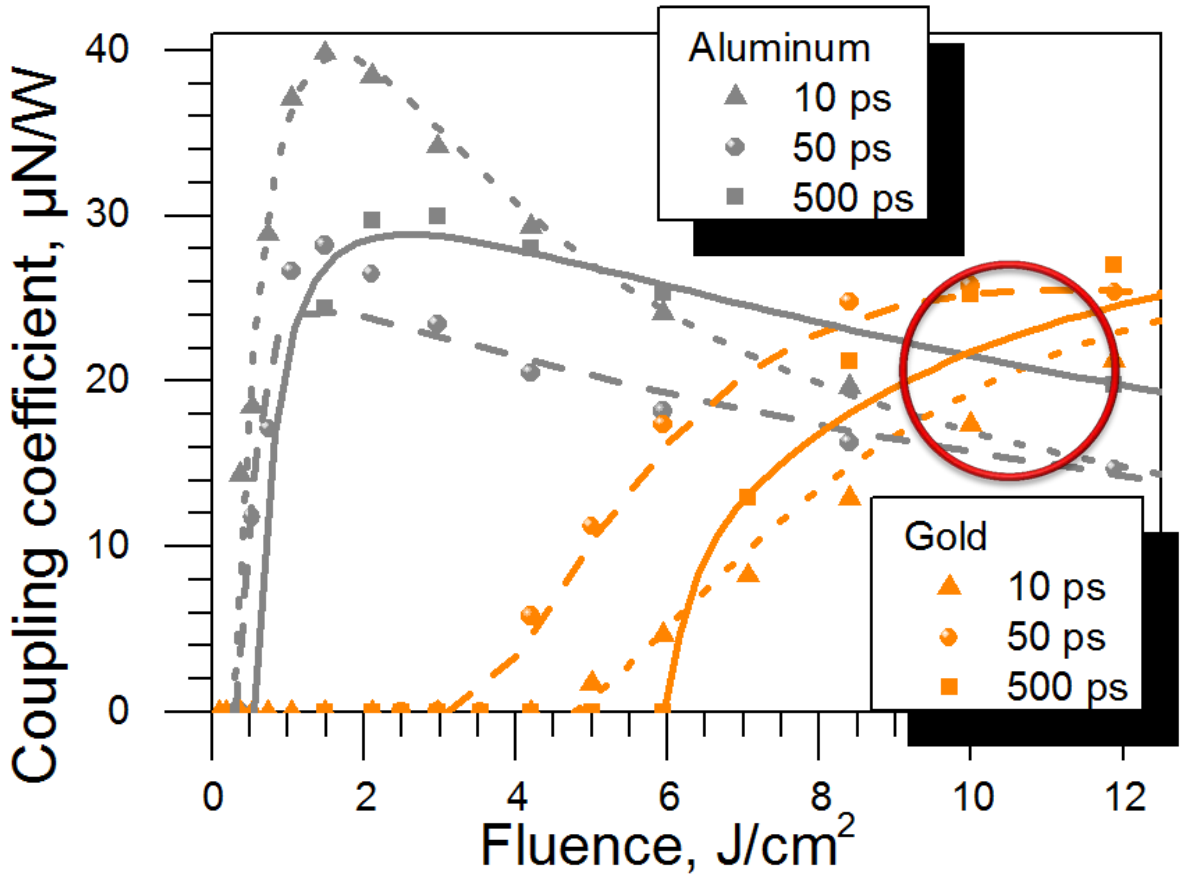
Thrust-to-laser-power ratio shows minor dependence on pulse duration

- Laser-wavelength
  λ = 1064 nm
- Angle of incidence
  ϑ = 0°
- Circular
  polarization



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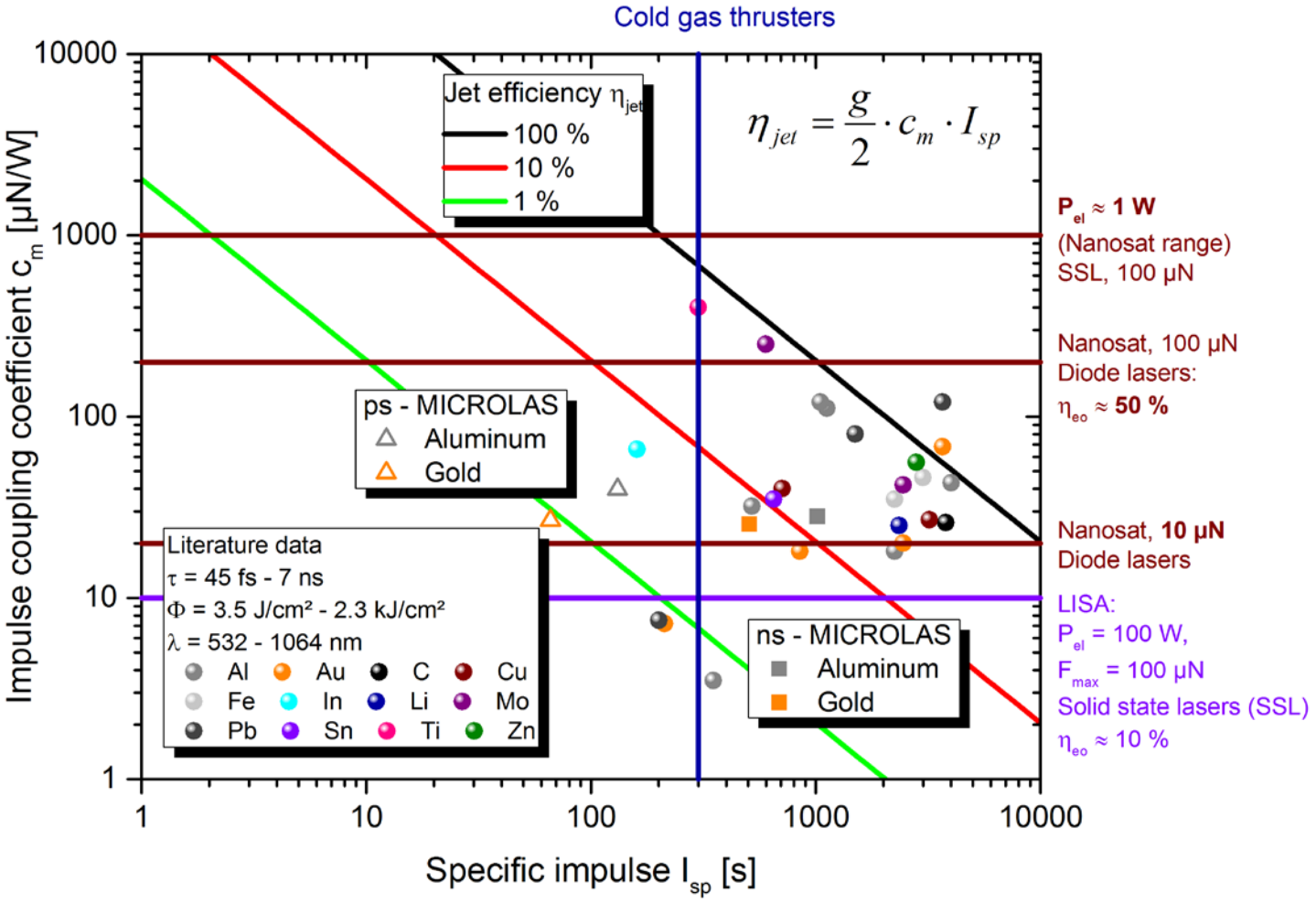
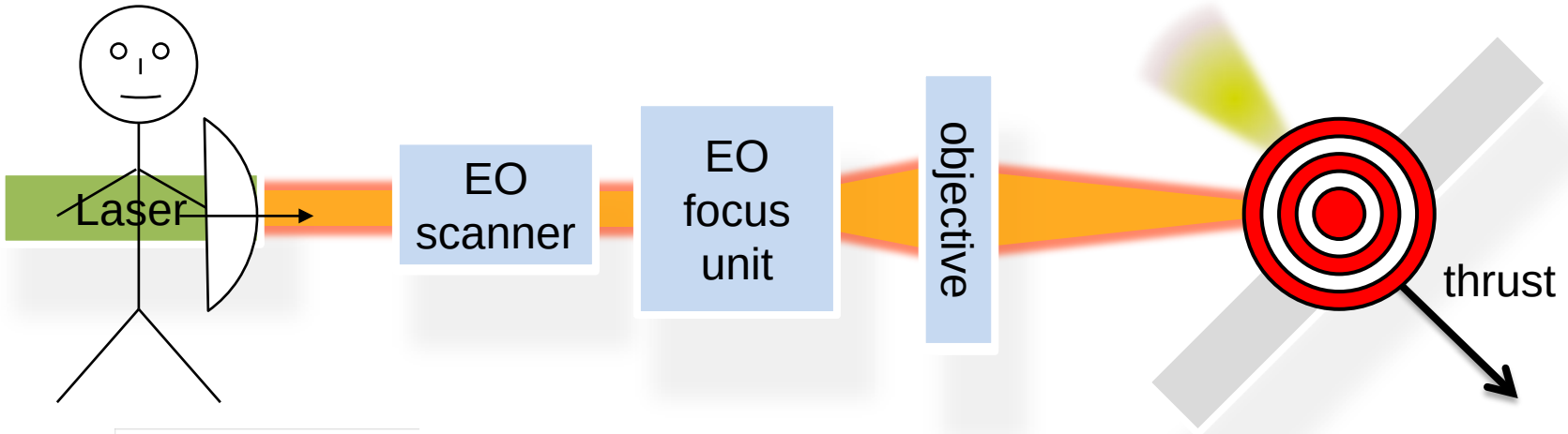
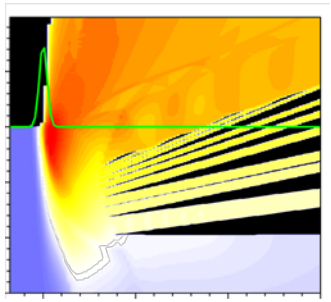
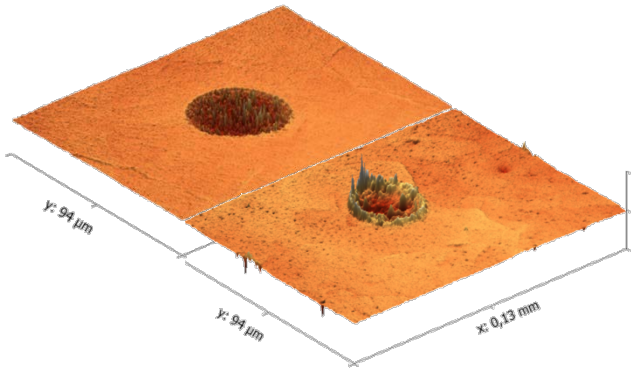
Specifications

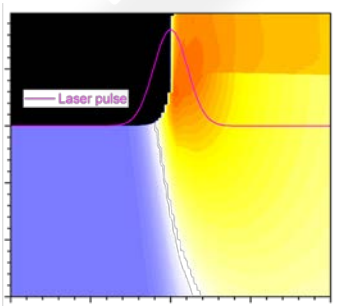


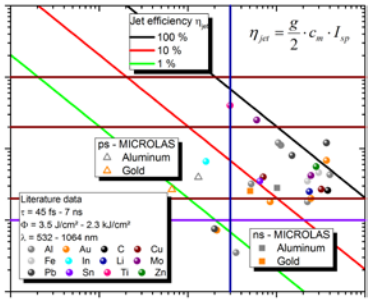
Summary

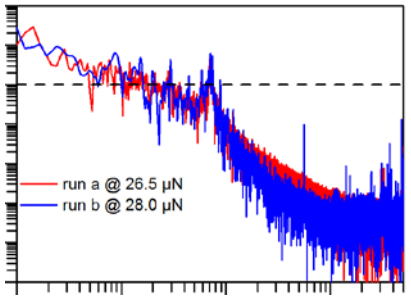

Laser
EO scanner
EO focus unit
objective
thrust




y: 94 µm
y: 94 µm
x: 0,13 mm
0,35 µm
-0,35 µm

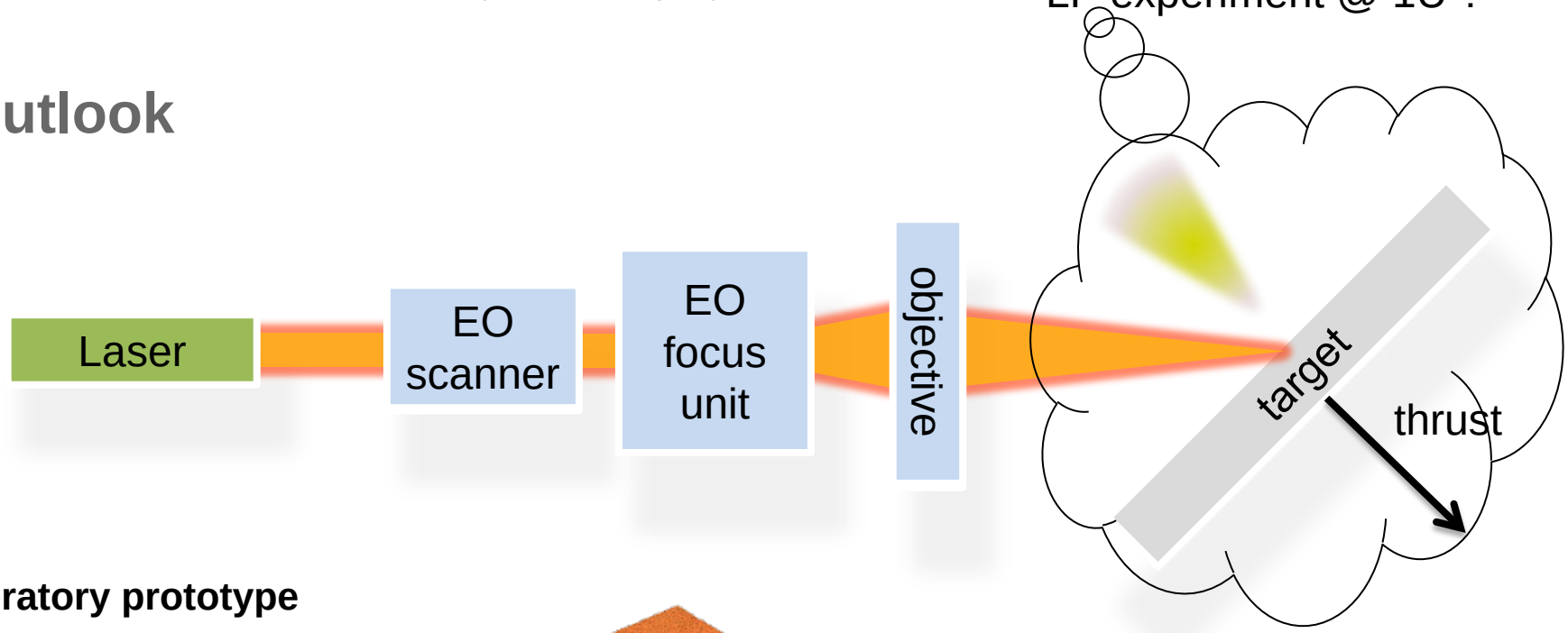

Laser pulse


Jet efficiency
100 %
10 %
1 %
ps - MICROLAS
Aluminum
Gold
Literature data
ns - MICROLAS
Aluminum
Gold


run a @ 26.5 µN
run b @ 28.0 µN

Outlook

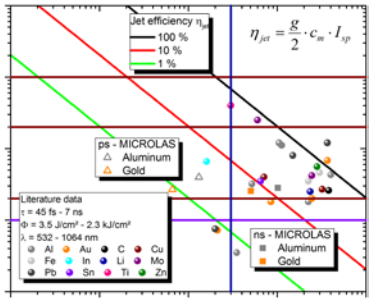
LP experiment @ 1U ?

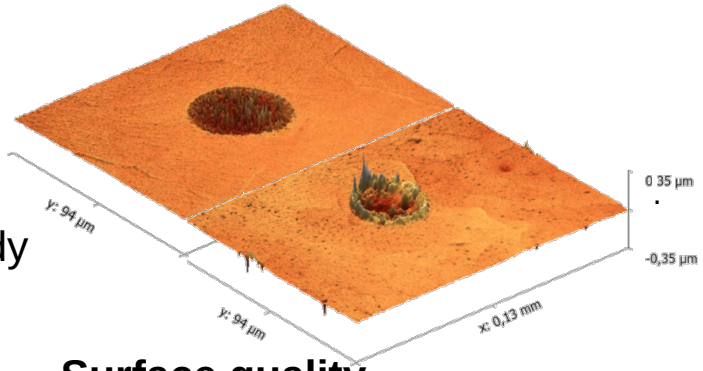


Laboratory prototype

Optimum working point

- Wide-range parameter study



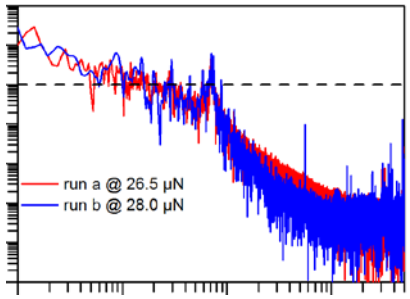


Surface quality

- Ablation and profilometry
- 3D simulation
- *Var. materials*
- *Var. laser pulse lengths*

Thrust noise

- Thrust measurements
- 3D simulation
- Control loop



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Precise thrust generation in the µN range by laser ablation

We want to thank …

Dr. Mikhail Povarnitsyn, Joint Institute for High Temperatures, Russian Academy of Sciences (RAS), Moscow

Lisa Pastuschka, Daniel Förster, Institut für Strahlwerkzeuge (IFSW), University of Stuttgart

PD Dr. Johannes Roth, Institute for Functional Materials and Quantum Technologies (FMQ), University of Stuttgart

… you for your attention!